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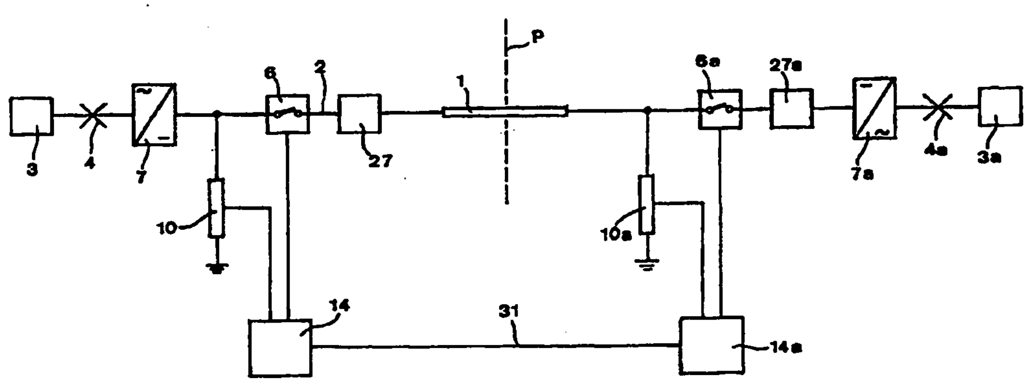

(57) Abstract

The device according to the invention is adapted to protect, in an electric power plant, objects (1, 7, 27) against fault-related over-currents, said objects being connected to an electric power network (3) or another equipment in the electric power plant. An over-current reducing arrangement (5) is connected to a line (2), which interconnects the network/equipment (3) and the object (1, 7, 27), said arrangement being actuatable for over-current reduction with the assistance of an over-current condition detecting arrangement.

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A DEVICE AND A METHOD FOR PROTECTING AN OBJECT AGAINST FAULT-RELATED OVER-CURRENTS

FIELD OF THE INVENTION AND PRIOR ART

This invention is related to a device according to the pre-characterising part of claim 1. Besides, the invention comprises a method for protecting the object against over-currents.

The electric object may be of arbitrary nature as long as it is included in an electric power network and requires protection against fault-related over-currents, i.e. in practice short-circuit currents. As an example, it may be mentioned that the object may be formed by an electric apparatus having a magnetic circuit, e.g. a generator, transformer or motor. Also other objects may be in question, for instance switch gear equipment etc. The present invention is intended to be applied in connection with medium or high voltage. According to IEC norm, medium voltage refers to 1-72.5 kV whereas high voltage is >72.5 kV. Thus, transmission, sub-transmission and distribution levels are included.

However, in connection with the present invention the objects to be protected are primarily formed by one or more constituents in a HVDC-plant (HVDC = High Voltage Direct Current). An object in this connection may be formed by a power line, in particular a cable. The application according to the invention is particularly interesting in connection with submerged cables since those present particular problems from the point of view of protection due to the submarine location. Submerged cables are also often very extended, which means that substantial energy amounts may be stored in the cables. However, it is in this connection empha-

sised that the solution according to the invention is not restricted only to HVDC-plants. Thus, the invention may also be applied in other situations where cables are used for electric power transmission. Cases are included where the cable delivers not only alternating current but also direct current.

In prior power plants of this nature one has resorted to, for protection of the object in question, a conventional circuit-breaker (switching device) of such a design that it provides galvanic separation on breaking. Since this circuit breaker must be designed to be able to break very high currents and voltages, it will obtain a comparatively bulky design with large inertia, which reflects itself in a comparatively long break-time. It is pointed out that the over-current primarily intended may be of varying nature depending on the fault case in view. As an example, the fault current may be formed by the short-circuit current occurring in connection with the protected object, for instance as a consequence of faults in the electric insulation system of the protected object. Such faults means that the fault current (short-circuit current) of the external network/equipment will tend to flow through the arc. The result may be a very large breakdown. It may be mentioned that for the Swedish power network, the dimensioning short-circuit current/fault-current is 63 kA. In reality, the short-circuit current may amount to 40-50 kA.

In case the fault resides in the insulation system of the cable, the fault-current will tend to flow from the network towards the fault and, accordingly, through at least parts of the cable and equipment between the same and the network, for instance a HVDC-plant with valves, smoothing capacitors etc. It is desirable to rapidly reduce the fault-current to minimise the damages on the cable. It is also essential to rapidly reduce the fault-current to the HVDC-plant from the network. However, this aspect is not the subject matter of the present invention. A further fault situation is a consequence of the fact that the cable, in particular when the same has a substantial extent, may have a very large amount of stored energy, which for instance in connection with a fault in the HVDC-plant or other equipment connected to the cable will give rise to a substantial fault-current from the cable to the HVDC-plant or equipment

present between said plant and the cable. Also in this regard an efficient protection function would be desirable. Finally, the fault may also be present beyond the opposite cable end, a fact which may involve a tendency to a fault current flowing from the opposite cable end towards the adjacent cable end and there may cause damages.

A problem with said circuit-breaker is the long break-time thereof. The dimensioning break-time (IEC-norm) for completely accomplished breaking is 150 milliseconds (ms). It is associated to difficulties to reduce this break-time to less than 50-130 ms depending upon the actual case. The consequence thereof is that when there is a fault in the protected object, a very high current will flow through the same during the entire time required for actuating the circuit-breaker to break. During this time the full fault current of the external power network involves a considerable load on the protected object. In order to avoid damage and complete break-down with respect to the protected object, one has, according to the prior art, tried to construct the object so that it manages, without appreciable damage, to be subjected to the short-circuit current/fault current during the break-time of the circuit breaker. It is pointed out that a short-circuit current (fault current) in the protected object may be composed of the own contribution of the object to the fault current and the current addition emanating from the network/equipment. The own contribution of the object to the fault current is not influenced by the functioning of the circuit-breaker but the contribution to the fault current from the network/equipment depends upon the operation of the circuit breaker. The requirement for constructing the protected object so that it may withstand a high short-circuit current/fault current during a considerable time period means substantial disadvantages in the form of more expensive design and reduced performance.

OBJECT OF THE INVENTION

The object of the present invention is to devise ways to design the device and the method so as to achieve better protection for the object and, accordingly, a reduced load on the same when a fault occurs. This means an increased safety to failures or alternatively, that the object it-

self does not have to be designed to withstand a maximum of short-circuit currents/fault currents during relatively long time periods.

A sub-object of the invention is to provide a solution particularly useful in HVDC-plants and/or plants involving use of a cable for electric power transmission.

SUMMARY OF THE INVENTION

According to the invention the object outlined hereinabove is obtained by an over-current reducing arrangement being connected to the line, said arrangement being actuatable for over-current reduction with the assistance of an over-current condition detecting arrangement.

It is particularly preferred that a switching device is arranged in the line between the network/equipment and the object and that the over-current reducing arrangement is actuatable for over-current reduction within a time period substantially less than the break-time of the switching device.

Furthermore, it is preferred that the over-current reducing arrangement comprises an over-current diverter for diversion of over-current to earth or otherwise another unit having a lower potential than the network/equipment.

Thus, the invention is based upon the principle not to rely for breaking purposes only upon a switching device which finally establishes galvanic separation, but instead use a rapidly operating over-current reducing arrangement, which, without effecting any real breaking of the over-current, nevertheless reduces the same to such an extent that the object under protection will be subjected to substantially reduced strains and, accordingly, a smaller amount of damages. The reduced over-current/fault current means, accordingly, that when the switching device establishes galvanic separation, the total energy injection into the protected object will have been much smaller than in absence of the over-current r ducing arrangem nt.

According to a particularly preferred embodiment of the invention, measures have been taken to obtain a reduction of the time-period, during which the current already reduced by means of the over-current reducing arrangement may flow into the protected object. For this purpose the device comprises a further breaker arranged in the line between the circuit breaker and the object, said further breaker being designed to break at a lower voltage and current than the switching device and therefore may be designed with a shorter break-time than the switching device as a consequence of a smaller need for movement and a smaller weight of the movable contact(s) of the breaker, said further breaker being arranged to break not until a time when the over-current towards or away from the protected object has been reduced by means of the over-current reducing arrangement. More specifically, the movement required of the movable contact(s) of the further breaker is smaller due to lower voltage whereas the weight of the contact(s) may be held lower due to the fact that the lower current does not require such large contact areas.

In order to fulfil the various fault protection functions which may be required, the invention contemplates that the over-current diverter and the further breaker may be present in plurality. An essential factor in this regard for dimensioning and control is that the fault-current in a certain fault situation should be able to reach the over-current diverter without having to pass any such further breaker which one believes should be open. Instead, the further breaker should then be located such that the current which must be broken by the further breaker has been reduced as a consequence of the operation of the over-current diverter.

Further advantages and features of the invention, particularly with respect to the method according to the invention, appear from the following description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

With r ference to the enclosed drawings, a more specific description of an embodiment example of th invention follows hereinafter.

In the drawings:

Fig. 1 is a purely diagrammatical view illustrating the basic aspects behind the solution according to the invention,

Figs. 2a-2d are diagrams illustrating in a diagrammatical form and in a comparative way fault current developments and the energy development with and without the protection device according to the invention;

Fig. 3 is a diagrammatical view illustrating a conceivable design of a device according to the invention;

Fig. 4 is a diagrammatical view illustrating a possible design of the over-current reducing arrangement; and

Fig. 5 is a diagrammatical view illustrating the device according to the invention applied in an electrical power plant comprising HVDC-valves, capacitor banks, reactors etc.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

An electric power plant comprising a protected object 1 is shown in fig. 1. The object consists in the example of an electric power cable, in particular a submarine cable, the length of which may be considerable. Also further protected objects may be said to be at hand in the example, namely those denoted 7 and 27. The object 7 is formed by a HVDC-valve. It should be noted that such a valve is very comprehensive and comprises, as a rule, a protection equipment of its own in the form of a circuit breaker. Such a circuit breaker is indicated in fig. 1 at 4. This circuit breaker may be entirely separate from the HVDC-valve 7 but it may be considered to be represented by a circuit breaker contained in the HVDC-valve. The object 27 is in the example formed by some suitable auxiliary equipm nt, for instance filter capacitor banks, reactors etc.

A line generally denoted 2 connects the cable 1 to an external supply network 3. Instead of such a network, the unit denoted 3 could be formed by some other equipment contained in the electric power plant. The power plant involved is conceived to be of such a nature that it is the object 1 itself which primarily is intended to be protected against fault currents from the network/equipment 3 when there occurs a fault in the object 1 giving rise to a fault current from the network/equipment 3 towards the object 1 so that the fault current will flow through the object. Said fault may consist in a short-circuit having been formed in the object 1. A short-circuit is a conduction path, which is not intended, between two or more points. The short-circuit may for instance consist of an arc. This short-circuit and the resulting violent current flow may involve considerable damages and even a total break-down of the object 1.

It is pointed out already now that with at least some types of protected electrical objects 1, short-circuit currents/fault currents harmful to the object in question may flow from the protected object towards the network/equipment 3. Within the scope of the invention, it is intended to be used for protection purposes not only for protection of the object from externally emanating fault currents flowing towards the object but also from internal fault currents in the object flowing in the opposite direction. This will be discussed in more detail in the following.

In the following, the designation 3 will, to simplify the description, always be mentioned as consisting of an external power network. However, it should be kept in mind that some other equipment may be involved instead of such a network, as long as said equipment causes violent current flows through the object 1 when there is a fault.

A conventional circuit breaker 4 is arranged in the line 2 between the object 1 and the network 3. This circuit breaker comprises at least one own sensor for sensing circumstances indicative of the fact that there is an over-current flowing in the line 2. Such circumstances may be currents/voltages but also other indicating that a fault is at hand. For instance, the sensor may be an arc sensor or a sensor recording short-circuit sound etc. When the sensor indicates that the over-current

is over a certain level, the circuit breaker 4 is activated for breaking of the connection between the object 1 and the network 3. The circuit breaker 4 must, however, break the total short-circuit current/fault current. Thus, the circuit breaker must be designed to fulfil highly placed requirements, which in practice means that it will operate relatively slowly. In fig. 2a it is illustrated in a current/time-diagram that when a fault, for instance a short-circuit in the object 1, occurs at the time t_{fault}, the fault current in the line denoted 2 in fig. 1 rapidly assumes the magnitude i_1. This fault current i_1 is broken by means of the circuit breaker 4 at t_1, which is at least within 150 ms after t_{fault}. Fig 2d illustrates the diagram $i^2 \cdot t$ and, accordingly, the energy developed in the protected object 1 as a consequence of the short-circuit therein. The energy injection into the object occurring as a consequence of the short-circuit current is, accordingly, represented by the total area of the outer rectangle in fig. 2d.

It is in this connection pointed out that the fault current in figs. 2a-c and the currents in fig. 2d represent the envelope of the extreme value. Only one polarity has been drawn out in the diagram for the sake of simplicity.

The circuit breaker 4 is of such a design that it establishes galvanic separation by separation of metallic contacts. Accordingly, the circuit breaker 4 comprises, as a rule, required auxiliary equipment for arc extinguishing.

According to the invention the line 2 between the object 1 and the switching device 4 is connected to an arrangement reducing over-currents towards the apparatus 1 and generally denoted 5. The arrangement is actuatable for over-current reduction with the assistance of an over-current conditions detecting arrangement within a time period substantially less than the break-time of the circuit breaker 4. This arrangement 5 is, accordingly, designed such that it does not have to establish any galvanic separation. Therefore, conditions are created to very rapidly establish a current reduction without having to accomplish any total elimination of the current flowing from the network 3 towards the protected object 1. Fig 2b illustrates in contrast to the case according to fig.

2a that the over-current reducing arrangement 5 according to the invention is activated upon occurrence of a short-circuit current at the time t_{fault} for over-current reduction to the level i_2 at the time t_2. The time interval t_{fault}-t_2 represents, accordingly, the reaction time of the over-current reducing arrangement 5. The task of the arrangement 5 being not to break but only reduce the fault current, the arrangement may be caused to react extremely rapidly, which will be discussed more closely hereunder. As an example, it may be mentioned that current reduction from the level i_1 to the level i_2 is intended to be accomplished within one or a few ms after unacceptable over-current conditions having been detected. It is then aimed at to accomplish the current reduction in a shorter time than 1 ms, and preferably more rapidly than 1 microsecond.

As appears from fig. 1, the device comprises a further breaker generally denoted 6 and arranged in the line 2 between the circuit breaker 4 and the object 1. This further breaker is designed to break at lower voltage and currents than the circuit breaker 4 and may, as a consequence thereof, be designed to operate with shorter break-times than the circuit breaker. The further breaker 6 is arranged to break not until after the over-current from the network 3 towards the object 1 has been reduced by means of the over-current reducing arrangement 5 but substantially earlier than the circuit breaker 4. From that stated, it appears that the further breaker 6 should be coupled to the line 2 in such a way that it is the current reduced by means of the over-current reducing arrangement 5 which will flow through the further breaker and which, accordingly, is to be broken by means thereof.

Fig 2b illustrates the action of the further breaker 6. This breaker is, more specifically, designed to break at the time t_3, which means that the duration of the current i_2 reduced by means of the over-current reducing arrangement 5 is substantially delimited, namely to the time period t_2-t_3. The consequence is that the energy injection into the protected object 1 caused by a fault current from the network 3 is represented by the surfaces marked with oblique lin s in fig. 2d. It appears that a drastic reduction of the energy injection is achieved. In this connection it is pointed out that since, according to a specific model, the energy increases with

the square of the current, a reduction to one half of the current reduces the energy injection to a fourth. It is illustrated in fig. 2c how the fault current will flow through the arrangement 5.

The dimensioning of the arrangement 5 and the further breaker 6 is conceived to be carried out such that the arrangement 5 reduces the fault current and the voltage to be broken by means of the further breaker 6 to substantially lower levels. A realistic break-time as to the further breaker 6 is 1 ms. However, the dimensioning should be made such that the breaker 6 is caused to break not until after the arrangement 5 having reduced the current flowing through the breaker 6 to at least a substantial degree.

It is illustrated in more detail in fig. 3 how the device may be realised. It is then pointed out that the invention is applicable in direct current (also HVDC = High Voltage Direct Current) and alternating-current connections. In the latter case, the line denoted 2 may be considered to form one of the phases in a multiphase alternating-current system. However, it should be kept in mind that the device according to the invention may be realised so that either all phases are subjected to the protection function according to the invention in case of a detected fault or that only that phase or those phases where a fault current occurs which are subjected to current reduction.

It appears from fig. 3 that the over-current reducing arrangement generally denoted 5 comprises an over-current diverter 7 for diverting over-currents to earth 8 or otherwise another unit having a lower potential than the network 3. Thus, the over-current diverter may be considered as forming a current divider which rapidly establishes a short-circuit to earth or otherwise a low potential 8 for the purpose of diverting at least a substantial part of the current flowing in the line 2 so that said current does not reach the object 1 to be protected. If there is a serious fault in the object 1, for instance a short-circuit, which is of the same magnitude as the short-circuit that the over-current diverter 7 is capable of establishing, it may be said that generally speaking a reduction to one half of the current flowing to the object 1 from the network 3 is achiev d as a

consequence of the over-current diverter 10 in case the fault is close to the latter. In comparison with fig. 2b, it appears, accordingly, that the current level i_2 illustrated therein and being indicated to amount to approximately half of i_1 may be said to represent the worst occurring case. Under normal conditions, the purpose is that the over-current diverter 10 should be able to establish a short-circuit having a better conductivity than the one corresponding to the short-circuit fault in the object 1 to be protected so that accordingly a main part of the fault current is diverted to earth or otherwise a lower potential via the over-current diverter 10. It appears from this that, accordingly, in a normal fault case, the energy injection into the object 1 in case of a fault becomes substantially smaller than that which is indicated in fig. 2d as a consequence of lower current level i_2 as well as shorter time span t_2-t_3.

The over-current diverter 10 comprises switch means coupled between earth 8 or said lower potential and the line 2 between the object 1 and the network 3. This switch means comprises a control member 9 and a switch member 10. This switch member may for instance be formed by at least one semiconductor component, for instance a thyristor, which is open in a normal state, i.e. isolating in relation to earth, but via the control member 9 may be brought into an active, conducting state in a very short time in order to establish current reduction by diversion to earth.

Fig 3 illustrates that an over-current conditions detecting arrangement may comprise at least one and preferably several sensors 11-13 suitable for detecting such over-current situations requiring activation of the protection function. As also appears from fig. 3, these sensors may include the sensor denoted 13 located in the object 1 or in its vicinity. Furthermore, the detector arrangement comprises a sensor 11 adapted to sense over-current conditions in the line 2 upstreams of the connection of the over-current reducing arrangement 5 and the line 2. As is also explained in the following, it is suitable that a further sensor 12 is provided to sense the current flowing in the line 2 towards the object 1 to be protected, i.e. the current which has been reduced by means of the over-current reducing arrangement 5. In addition, it is pointed out that the sensor 12, as well as possibly the sensor 13, is capable of sensing the

current flowing in the line 2 in a direction away from the object 1, for instance in cases where energy magnetically stored in the object 1 gives rise to a current directed away from the object 1.

It is pointed out that the sensors 11-13 do not necessarily have to be constituted by only current and/or voltage sensing sensors. Within the scope of the invention, the sensors may be of such nature that they generally speaking may sense any conditions indicative of the occurrence of a fault of the nature requiring initiation of a protection function.

In cases where such a fault occurs that the fault current will flow in a direction away from the object 1, the device is designed such that the control unit 14 thereof will control the further breaker 6 to closing, in case it would have been open, and, in addition, the over-current reducing arrangement 5 is activated such that the short-circuit current may be diverted by means of the same.

When, for example, the object 1 is conceived to consist of a cable, the function on occurrence of a short-circuit therein could be such that the short-circuit first gives rise to a violent flow of current into the cable, which flow is detected and gives rise to activation of the arrangement 5 for the purpose of current diversion. When the current flowing towards the generator 1 has been reduced in a required degree, the breaker 6 is caused to break, but, controlled by means of the control unit 14, not earlier than leaving time for the energy, in occurring cases, magnetically stored in the cable 1 to flow away from the cable 1 and be diverted via the arrangement 5. In the latter case the diversion of the stored energy means, accordingly, that other constituents in the plant, for example the HVDC-valve 7, are protected from the influence of the fault current.

Furthermore, the device comprises a control unit generally denoted 14. This is connected to the sensors 11-13, to the over-current reducing arrangement 5 and to the further breaker 6. The operation is such that when the control unit 14 via one or more of the sensors 11-13 receives signals indicating occurrence of unacceptable fault currents towards the object 1, the over-current reducing arrangement 5 is immediately con-

trolled to rapidly provide the required current reduction. The control unit 14 may be arranged such that when the sensor 12 has sensed that the current or voltage has been reduced to a sufficient degree, it controls the breaker 6 to obtain operation thereof for breaking when the over-current is below a predetermined level. Such a design ensures that the breaker 6 is not caused to break until the current really has been reduced to such a degree that the breaker 6 is not given the task to break such a high current that it is not adequately dimensioned for that purpose. However, the embodiment may alternatively also be such that the breaker 6 is controlled to break a certain predetermined time after the over-current reducing arrangement having been controlled to carry out current reduction.

The circuit breaker 4 may comprise a detector arrangement of its own for detection of over-current situations or otherwise the circuit breaker may be controlled via the control unit 14 based upon information from the same sensors 11-13 also controlling the operation of the over-current reducing arrangement.

It is illustrated in fig. 3 that the further breaker 6 comprises a switch 15 having metallic contacts. This switch 15 is operable between breaking and closing positions by means of an operating member 16, which in turn is controlled by the control unit 14. A shunt line 17 is connected in parallel over this switch 15, said shunt line comprising one or more components 18 intended to avoid arcs on separation of the contacts of the switch 15 by causing the shunt line 17 to take over the current conduction from the contacts. These components are designed so that they may break or restrict the current. Thus, the purpose is that the components 18 normally should keep the conduction path in the shunt line 17 interrupted but close the shunt line when the switch 15 is to be opened so that accordingly the current is shunted past the switch 15 and in that way arcs do not occur or possibly occurring arcs are efficiently extinguished. The components 18 comprise one or more associated control members 19 connected to the control unit 14 for control purposes. According to one embodiment of the invention, said components 18 are

controllable semiconductor components, for instance GTO thyristors, having necessary over-voltage arresters 30.

A disconnector 20 for galvanic separation in the current conduction path created by means of the shunt line 17 to the object 1 to be protected is arranged in series with said one or more components 18. This disconnector 20 is via an operating member 21 controlled by the control unit 14. The disconnector 20 is illustrated in fig. 3 as being placed in the shunt line 17 itself. This is of course not necessary. The disconnector 20 could also be placed in the line 2 as long as it ensures real galvanic separation, by series coupling with said one or more components 18, in the conduction path established by means of said series coupling so that accordingly there is not any possibility for current to flow through the components 18.

The device as it has been described so far operates in the following manner: In absence of a fault, the circuit breaker 4 is closed just like the switch 15 of the further breaker 6. The components 18 in the shunt line 17 are in a non-conducting state. The disconnector 20 is closed. Finally, the switch means 10 of the over-current reducing arrangement 5 is open, i.e. it is in a non-conducting state. In this situation the switch means 10 must, of course, have an adequate electrical strength so that it is not inadvertently brought into a conducting state. Over-voltage conditions occurring in the line 2 as a consequence of atmospheric (lightning stroke) circumstances or coupling measures may, accordingly, not involve the voltage strength of the switch means 10 in its non-conducting state to be exceeded. For this purpose it is suitable to couple at least one over-voltage arrester 22 in parallel with the switch means 10. In the example such over-voltage arresters are illustrated on both sides of the switch means 10. Accordingly, the over-voltage arresters have the purpose to divert such over-voltages which otherwise could involve a risk for inadvertent break-through in the switch means 10.

When an over-current state has been registered by means of some of the sensors 11-13 or the own sensor (it is of course realised that information from the own sensor of the circuit breaker 4 may be used as a

basis for control of the over-current reducing arrangement 5 according to the invention) of the circuit breaker 4 and this over-current state is of such magnitude that a serious fault of the object 1 is expected to be at hand, a breaking operation is initiated as far as the circuit breaker 4 is concerned. In addition, the control unit 14 controls the over-current reducing arrangement 5 to effect such reduction, and this more specifically by bringing, via the control member 9, the switch means 10 into an electrically conducting state. As described before, this may occur very rapidly, i.e. in a fraction of the time required for breaking by means of the circuit breaker 4, for what reason the object 1 to be protected immediately is liberated from the full short-circuit current from the network 3 as a consequence of the switch means 10 diverting at least an essential part, and in practice the main part, of the current to earth or otherwise a lower potential. As soon as the current, which flows towards the object 1 via the further breaker 6, has been reduced in a required degree, which can be established on a pure time basis by a time difference between activation of the switch means 10 and operation of the breaker 6, or by sensing of the current flowing in the line 2 by means of, for instance, the sensor 12, the operating member 16 of the switch 15 is, via the control unit 14, controlled to open the contacts of the switch 15. For extinguishing or avoiding arcs, the components 18, e.g. GTO thyristors or gas switches, are via the control members 19 controlled to establish conductivity of the shunt line 17. When the switch 15 has been opened and, thus, provided galvanic separation, the component 18 is again controlled to bring the shunt line 17 into a non-conducting state. In that way the current from the network 3 towards the object 1 has been efficiently cut off. After having brought the shunt line 17 into a non-conducting state, galvanic separation may, in addition, be effected by means of the disconnector 20 by controlling the operating member 21 thereof from the control unit 14. When all these incidents have occurred, breaking by means of the circuit breaker 4 occurs as a last incident. It is important to note that the over-current reducing arrangement as well as the further breaker 6 according to a first embodiment can be operated repeatedly. Thus, when it has been established by means of the sensors 11-13 that the circuit breaker 4 has been brought to cut off, the switch means 10 is reset to a non-conducting state and the switch 15 and th disconnector

20 are again closed so that when the circuit breaker 4 next time closes, the protection device is completely operable. According to another embodiment, it is, however, contemplated that the over-current reducing arrangement 5 may require exchange of one or more parts in order to operate again.

It is pointed out that according to an alternative embodiment of the invention, the component or components 18 could be brought into a conducting state as soon as the over-current reducing arrangement 5 has been brought into a closing state and this independently of whether the switch 15 possibly is not opened thereafter. The control of the components 18 could then, as described before, occur via the control unit 14 or, alternatively, by means of a control function involving a slavish following of the closing of the arrangement 5.

In the description given hereinabove with regard to the operation, it has not been taken into consideration that the HVDC-valve 7 by its constituents could be capable of, depending upon the design, breaking or restricting the fault current that has occurred as a consequence of an insulation fault in the object 1 before the circuit breaker 4 manages to effect such breaking. It may occur that the fault that has arisen also means that the HVDC-valve 7 is caused to be inoperative in a more or less serious manner.

In the description given hereinabove, only that part of the plant which is present on the left side of the dividing plane p in fig. 1 has been considered. This dividing plane p has here been drawn as being located at the middle of the cable 1, which is diagrammatically indicated. On the right side of this dividing plane p there is, of course, the counter part of the components located to the left; the components to the right are indicated with the same designations, only the letter a has been added.

It is pointed out that in the fault function described, the arrangement to the left of the dividing plane p means that closing of the switch means 10 also involv s a protection for the component 27 when the fault is present

in the cable. Also the further breaker 6 will provide protection for the component 27.

To the right of the dividing plane p in fig. 1 a like structure as the one to the left is present, with the only exception that the component 27a has obtained a somewhat different location. Furthermore, the further breaker 6a is placed differently than to the left of the dividing plane p. The circumstances described are caused by the fact that the main electric power transmission direction according to the embodiment according to fig. 1 is conceived to be in accordance with arrow A, i.e. to the right in fig. 1. With this as background, it is realised that the location of the component 27a to the right in fig. 1 and to the right of the switch means 10 and also to the right of the further breaker 6a means that in case a fault current would tend to flow in a direction to the right in fig. 1, the component 27a is located on the protected side of the switch means 10a and the breaker 6a. Furthermore, the switch means 10a will be able to take care of and to divert to earth over-currents arriving from the left in fig. 1 whereas the further breaker 6a serves for breaking, comparatively rapidly, of the line towards the HVDC-valve 7a present to the right and the feeding receiving network 3a present therein. Further aspects with regard to different protection situations will be discussed hereunder with the assistance of fig. 5.

Fig 4 illustrates an alternative embodiment of the over-current reducing arrangement 5. Instead of relying on a semiconductor switch means as in fig. 3, the embodiment according to fig. 4 is intended to involve causing of a medium present in a gap 24 between electrodes 23 to assume electrical conductivity by means of a control member 9a. This control member is arranged to control the operation of members 25 for causing or at least initiating the medium or a part thereof in the gap 24 into a conducting state. Said member 25 is in the example arranged to cause the medium in the gap 24 to assume electrical conductivity by causing or at least assisting in causing the medium to ionisation/plasma. It is preferred that the members 25 comprise at least one laser, which by energy supply to the medium in the gap 24 provides for the ionisation. As appears from fig. 4, a mirror 26 may be used for necessary diverting of the

laser beam bundle. It is in this connection pointed out that the embodiment according to fig. 4 may be such that the means 25 do not alone give rise to ionisation/plasma in the entire electrode gap. Thus, the intention may be that an electrical field imposed over the gap should contribute in ionisation/plasma formation, only a part of the medium in the gap being ionised by means of the members 25 so that thereafter the electrical field in the gap gives rise to establishment of plasma in the entire gap. It is in this connection pointed out that there may be in the electrode gap not only a medium consisting of various gases or gas mixtures but also vacuum. In the case of vacuum, initiation by means of laser occurs at at least one of the electrodes, which, accordingly, will function as an electron and ion transmitter for establishment of an ionised environment/a plasma in the electrode gap.

However, it is pointed out that the members 25 in the embodiment according to fig. 4 should be designed so that the electrode gap 24 between the electrodes 23 approximately momentarily are imparted conductivity as a consequence of the supply of radiation energy. According to a particularly preferred embodiment, the member 25 and the associated radiation directing equipment is designed so that the radiation energy is caused to form a substantially continuos, electrically conducting plasma channel between the electrodes. Such en embodiment means that the dependency upon an electrically driving field between the electrodes has been substantially reduced. With regard to fig. 1, a complementary comment must be given, namely that the two control units 14 and 14a at the two ends of the plant suitably communicate mutually via a connection denoted 31. In this way an individual control unit may take advantage of the information picked up by the sensors of the other control units so that, depending on the actual circumstances, co-ordinated protection measures are carried out.

With the assistance of fig. 5 further circumstances being of importance for the protection issue will be described. Initially the plant part to the left of the dividing plane p is discussed: in case the energy stored in the cable would risk to damag or otherwise interfere with the component 27, it is suitable to supplem nt with a further over-current diverter 10b placed

on that side of the component 27 which is opposite with respect to the over-current diverter 10. Besides, it is then also suitable to supplement with a further breaker 6b. In case the energy from the cable 1 would tend to flow in the direction to the left in fig. 5, this energy would be drained via the over-current diverter 10b and when the current has been reduced to a sufficient degree, the further breaker 6b could break so that the component 27 would be protected.

In case the HVDC-valve 7 or some other component forming the object 7 would require characterisation as sensitive to currents flowing to the left in fig. 5, a further breaker 6c, provided that the just mentioned further breaker 6b wouldn't exist, could be arranged to break the line 2 in a direction towards the object 7 after the over-current diverter 10 having reduced the size of the flowing current.

As to the situation to the right of the dividing plane p in fig. 5, it may be established that a further over-current diverter 10d could be arranged in connection with the line 2 on that side of the component 27a which is opposite to the diverter 10a so that accordingly the component 27a located on the opposite side of the component 27a as compared to the diverter 10a obtained an over-current diverter on both sides. This would primarily be an expression of a desire to protect the component 27a against currents flowing in the direction of arrow B. A further breaker 6d would then also be recommendable to apply in the line 2. This further breaker 6d would be intended to break the line 2 when the current therein has been reduced by means of the diverter 10d. The further breaker 6d would have to be placed in the line 2 between the connection of the diverter 10d and the component 27a to the line. In case a considerable fault-current could flow in the direction of the arrow B to the left in fig. 5, for instance as a consequence of a short-circuit in the cable 1 or to the left thereof and the diverter 10d and the further breaker 6d wouldn't be at hand, a further breaker 6d could be arranged in the line 2. This further breaker could then be located between the cable 1 and the connection of the diverter 10a to the line 2.

Although for the sake of clarity all over-current diverters and further breakers added in fig. 5 have not been shown as being in controllable connection with the respective control units 14, 14a this is in reality what is desired. The description shows that a very comprehensive protection of different constituents of the plant are possible in accordance with the invention.

It should be noted that the description presented hereinabove only should be considered as exemplifying for the inventive idea, on which the invention is built. Thus, it is obvious for the man skilled in the art that detail modifications may be made without leaving the scope of the invention. As an example, it may be mentioned that it would be possible to use as a switch means 10 a mechanical switch.

Claims

1. A device in an electric power plant for protection of one or more objects (1, 7, 27) connected to an electric power network (3) or another equipment included in the electric power plant from fault-related over-currents, **characterised** in that to a line (2) connecting the network/equipment (3) and the object (1, 7, 27) there is connected an over-current reducing arrangement (5), which is actuatable for over-current reduction with assistance of an over-current conditions detecting arrangement (11-13).

2. A device according to claim 1, **characterised** in that a switching device (4) is arranged in the line between the network/equipment (3) and the object (1, 7, 27) and that the over-current reducing arrangement (5) is actuatable for over-current reduction within a time period substantially shorter than the break-time of the switching device.

3. A device according to claim 2, **characterised** in that the switching device (4) is formed by a circuit-breaker.

4. A device according to claim 1 or 2, **characterised** in that the over-current reducing arrangement (5) comprises an over-current diverter (7) for diverting over-currents to earth (8) or otherwise another unit having a lower potential than the network/equipment.

5. A device according to claim 4, **characterised** in that the over-current diverter (7) comprises a switch means (10) coupled between earth or said lower potential and the line between the object (1) and the network/equipment (3).

6. A device according to claim 5, **characterised** in that the switch means (10) comprises at least one semiconductor component.

7. A device according to claim 5, **characterised** in that the switch means (10a) comprises an electrode gap (24) and m ans (25) for

causing or at least initiating the electrode gap or at least a part thereof to assume electrical conductivity.

8. A device according to claim 7, characterised by said means (25) for causing or at least initiating the electrode gap to assume electrical conductivity being arranged to cause the gap or a part thereof to assume the form of a plasma.

9. A device according to claim 8, characterised by said members (25) for causing or at least initiating the electrode gap or a part thereof to assume electrical conductivity comprising at least one laser.

10. A device according to any preceding claim, characterised in that it comprises a further breaker (6) arranged in the line between the switching device (4) and the object (1, 7, 27), said further breaker being arranged between the over-current reducing arrangement (5) and the object (1, 7, 27) and being adapted to break lower voltages and currents than the switching device (4) and therefore capable of performing a shorter break-time than the switching device, and that the further breaker is adapted to break when the over-current towards or away from the object (1) has been reduced by means of the over-current reducing arrangement (5) but substantially earlier than the switching device.

11. A device according to claim 10, characterised in that it comprises a control unit (14) connected to the detecting arrangement (11-13) and to the further breaker (6) in order to achieve actuation of the further breaker for breaking purposes when the over-current towards or away from the object (1) is indicated, by means of the detecting arrangement, to be under a predetermined level.

12. A device according to any of claims 10-11, characterised in that the further breaker (6) comprises a switch (15), over which there is coupled a shunt line (17) having one or more components (18) for avoiding arcs on separation of contacts of the switch (15) by causing the shunt line (17) to take over-current conduction from the contacts.

13. A device according to claim 12, characterised in that said one or more components (18) in the shunt line (17) are closable into conduction by means of control via the control unit (14).

14. A device according to claim 12 or 13, characterised in that said one or more components (18) are formed by controllable semiconductor components.

15. A device according to any of claims 12-14, characterised in that said one or more components (18) are provided with at least one over-voltage arrester (30).

16. A device according to any of claims 12-15, characterised in that a disconnector (20) for galvanic separation is arranged in series with said one or more components (18).

17. A device according to claim 16, characterised in that the disconnector (20) is coupled to the control unit (14) to be controlled thereof for opening after the switch (15) having been controlled to have closed and said one or more components (18) having been placed in a condition for breaking the shunt line (17).

18. A device according any preceding claim, characterised in that at least one over-voltage arrester (22) is coupled in parallel with the over-current reducing arrangement (5).

19. A device according to any of claims 1-18, characterised in that the object (1) comprises a power line, in particular a cable.

20. A device according to any preceding claim, characterised in that the object (7) comprises one or more constituents in a HVDC-plant.

21. A device according to any preceding claim, characterised in that the object (27) compris s a filter capacitor bank or reactor.

22. A device according to any preceding claim, characterised in that the protected object (1) comprises an electric apparatus having a magnetic circuit.

23. A device according to claim 22, characterised in that the object comprises a generator, transformer or motor.

24. A device according to any preceding claim, characterised in that two over-current reducing arrangements (5, 5a) are arranged on either sides of the object (1, 27) to protect the same from two sides.

25. A device according to claim 1, characterised in that it comprises a control unit (14) connected to the over-current reducing arrangement (5) and to the over-current conditions detecting arrangement (11-13), said control unit (14) being arranged to control the over-current reducing arrangement to closing based upon information from the over-current conditions detecting arrangement when required for reasons of protection.

26. A device according to claim 25 and one or more of the claims 10, 12 and 16, characterised in that one and the same control unit (14) is arranged to control, based upon information from the over-current conditions detecting arrangement (11-13), the over-current reducing arrangement (5) and the further breaker (6).

27. A device according to any of claims 10-26, characterised in that said at least one over-current diverter (10) is connected to the line (2) between two objects (1, 7, 27) to be protected and that two further breakers (6) occur, namely one further breaker located between the connection of the over-current diverter to the line and the respective object.

28. Use of a device according to any preceding claim for protection of an object against fault-related over-currents.

29. A method in an electric power plant for protection of one or more objects (1, 7, 27) connected to an electric power network (3) or another equipment included in the electric power plant from fault-related over-currents, **characterised** in that an over-current reducing arrangement (5) connected to the network/equipment and the object is activated for over-current reduction when over-current conditions have been detected by means of an arrangement (11-13) for such detection.

30. A method according to claim 29, **characterised** in that the over-current reducing arrangement (5) is activated for over-current reduction within a time period substantially less than the break-time of a switching device (4) connected in the line (2) between the object and the network/equipment.

31. A method according to claim 29 or 30, **characterised** in that over-currents are diverted to earth (8) or otherwise another unit having a lower potential than then the network/equipment by means of the over-current reducing arrangement (5).

32. A method according to claim 30 or 31, **characterised** in that a further breaker (6), which is arranged in the line between the switching device and the object and between the over-current reducing arrangement (5) and the object (1), is actuated for breaking after the over-current towards or away from the object (1) having been reduced by means of the over-current reducing arrangement (5).

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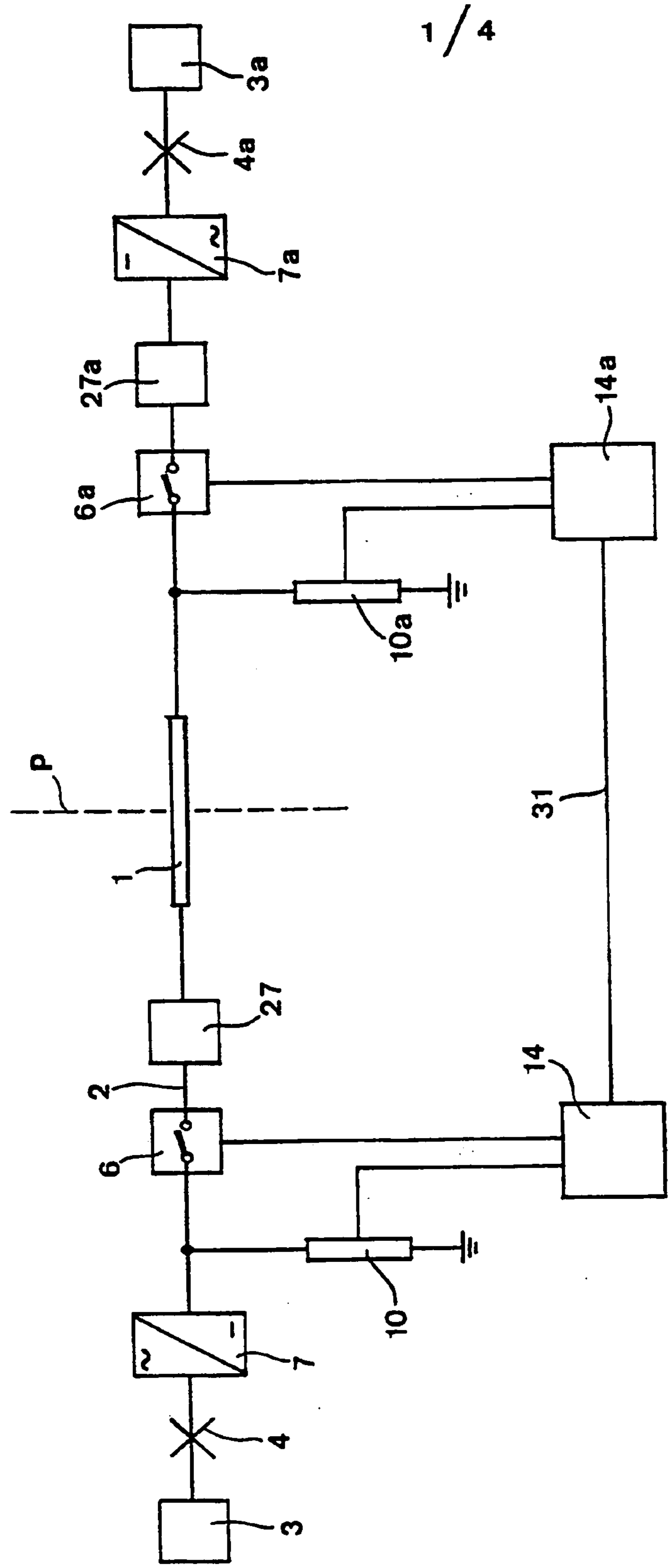

Fig 1

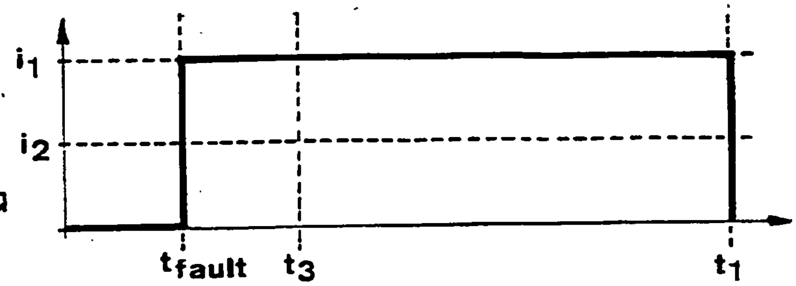

Fig 2a

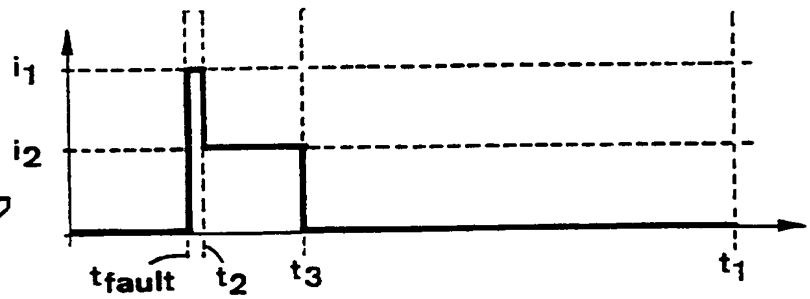

Fig 2b

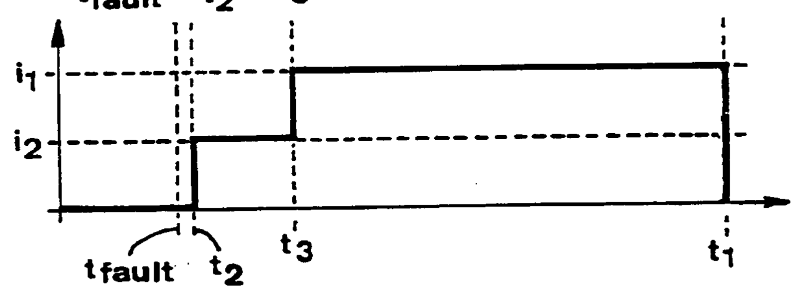

Fig 2c

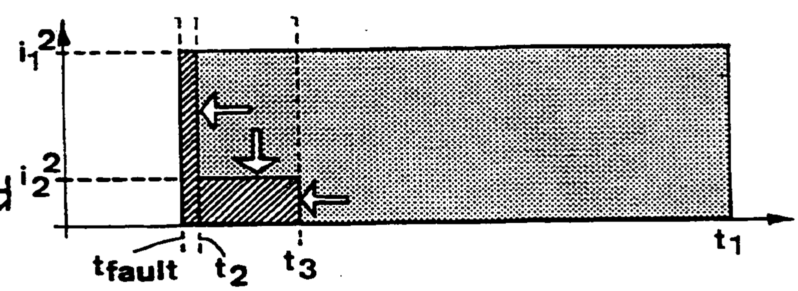

Fig 2d

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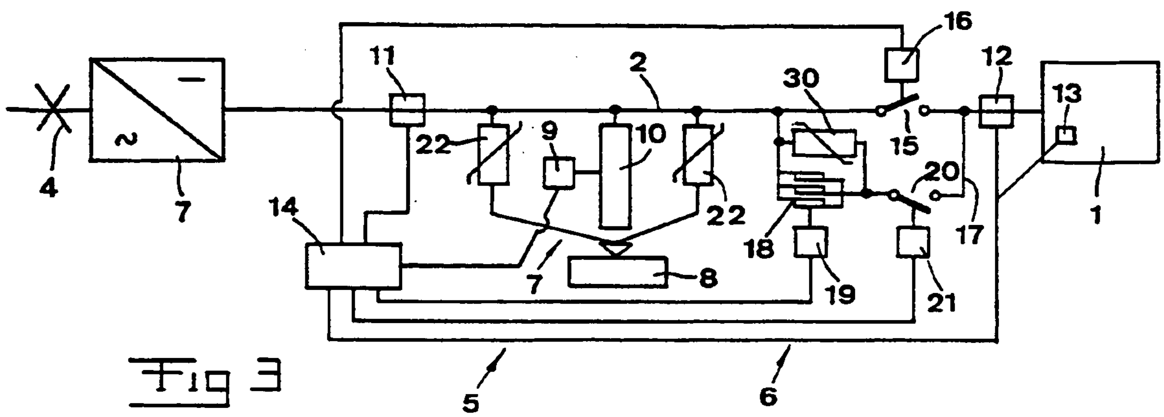
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Fig 3

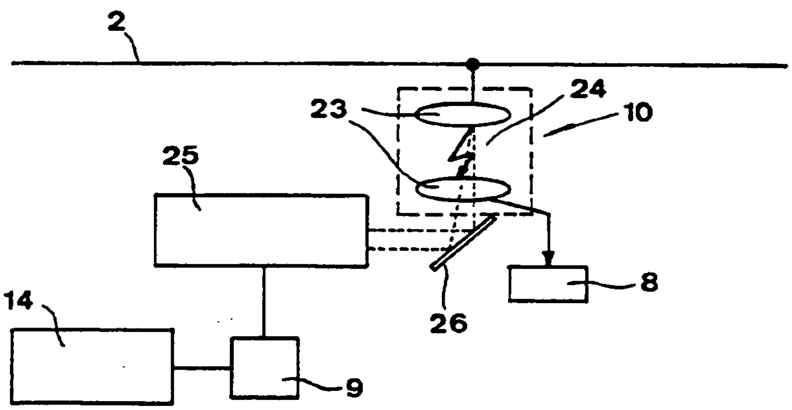
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Fig 4

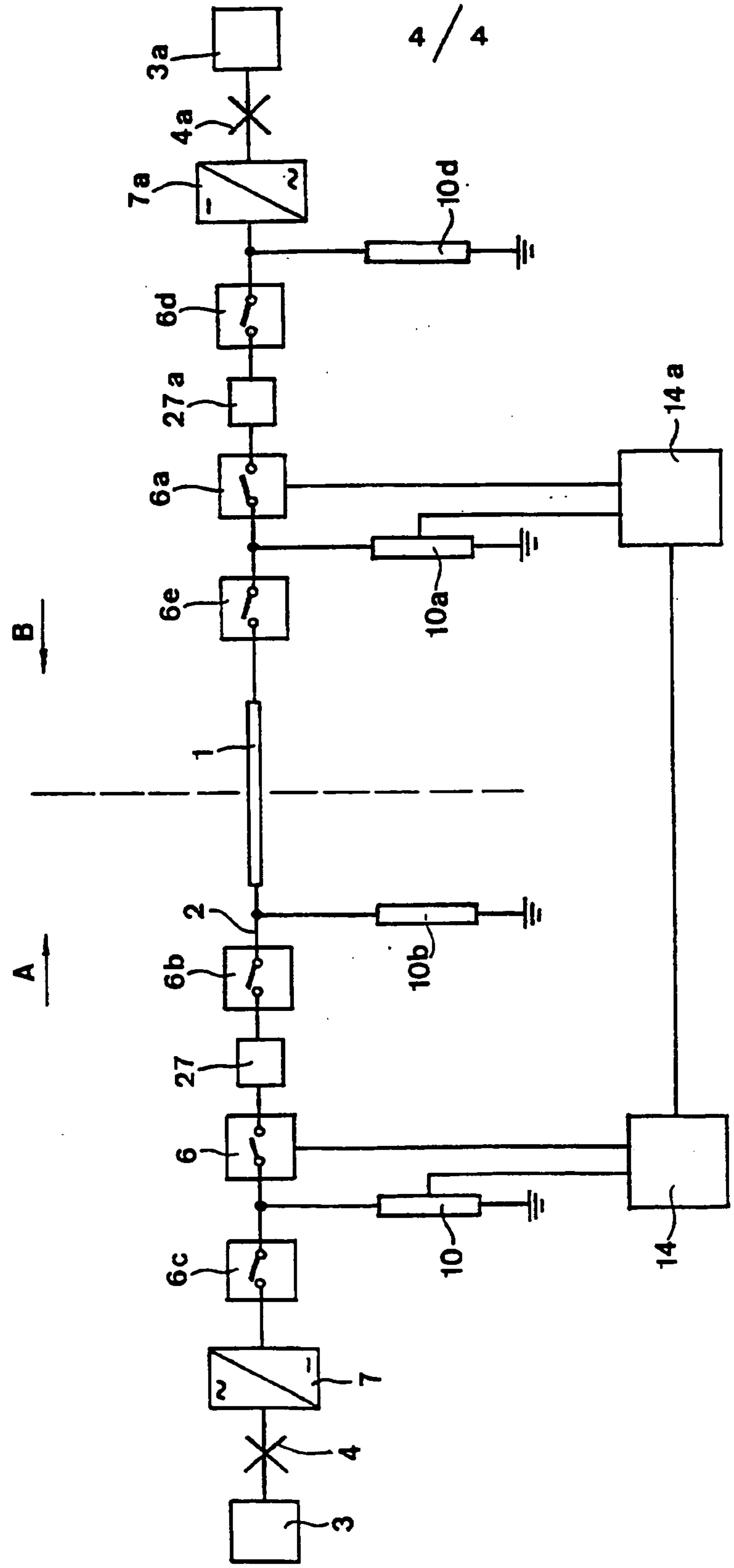

Fig 5

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